Landsat 7 Processing System (LPS) Operations Concept

Revision 2

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Landsat 7

Processing System (LPS)

Operations Concept

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Abstract

The Landsat 7 Processing System (LPS) Operations Concept describes the Landsat 7 spacecraft and ground system environment for operating the LPS, the procedures for coordinating the exchange of operational information between the LPS and its interfaces, acquiring wideband data from the LGS, processing it into Level 0R data files, and making them available to the Land Processes Distributed Active Archive Center (LP DAAC) for storing in its long-term archive.

The LPS operations concept described in this document is based on a preliminary understanding of the Earth Resources Observation System Data Center's (EDC's) current operations to support Landsat missions. Comments from EDC, as the key recipient of all LPS data files, are welcomed to align the LPS operations concept with EDC's operational and interface needs.

Key Words: Landsat 7 System
Landsat 7 Ground Station (LGS)
Landsat 7 Processing System (LPS)
Land Processes Distributed Active Archive Center (LP DAAC)
EROS Data Center (EDC)
Level 0R File(s)
Operations Concept

Preface

This document is maintained and controlled by the LPS Project Configuration Management Board (PCMB). This document can only be updated and revised by submitting the printed Document Change Notice (DCN) for approval by the PCMB. Comments and questions regarding this document should be directed to:

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Table of Contents

Section 1 — Introduction

Section 2 — LPS Overview

Section 3 — LPS Operations

Acronym List

Section 1 — Introduction

1.1 Purpose

The purpose of this document is to present the operations concepts envisioned by the LPS Project for the Landsat 7 Processing System (LPS), and to describe the functions performed by the LPS to support the overall Landsat 7 system and mission operations. The LPS is being developed by the Goddard Space Flight Center (GSFC) of the National Aeronautics and Space Administration (NASA) for operation at the Earth Resource Observation Satellites (EROS) Data Center (EDC) of the United States (US) Department of Interior (DOI). The EDC uses the Level 0R instrument data, browse image, and metadata files provided by the LPS to generate and to archive Landsat 7 image products and to distribute them to the Landsat national and international user communities. The LPS will be operated and maintained by the National Oceanographic and Atmospheric Administration (NOAA) of the U. S. Department of Commerce (DOC).

1.2 Scope

The LPS Operations Concept describes a systematic approach for exploiting the hardware, software and personnel resources of the LPS to support the Landsat 7 system and mission operations and users' objectives. In this respect, the LPS operations concept describes the Landsat 7 spacecraft and ground system environment for operating the LPS, the procedures for coordinating the exchange of operations management information between the LPS and its interfaces (the Landsat 7 Ground Station [LGS], the Mission Operations Center [MOC] and the Image Assessment System [IAS]), acquiring the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) wideband data from the LGS, processing it to Level 0R instrument data, browse image, and metadata files, and making them available to the Land Processes Distributed Active Archive Center (LP DAAC) for storing in the long-term archive. The LPS operations concept is based on the LPS being co-located with the LGS and the LP DAAC at the EDC.

This operations concept also describes operational support capabilities of the LPS including training and testing as envisioned by the LPS Project. The LPS operations concept document will be updated as necessary throughout the LPS system design phase, to reflect changes in the functional requirements and operational concept of the Landsat 7 System, the LPS and its operational interfaces, and in response to suggestions from EDC and NOAA to adapt to the Landsat system operations known at EDC.

No requirements for the receipt and processing of any data from the Landsat 7 Flight of Opportunity (LFO) instrument are defined by the Landsat 7 Project. As a result, this operations concept does not contain any description for the receipt, processing, or delivery of the LFO instrument data by the LPS.

1.3 Definitions

The following terms, as defined in this section, are commonly used throughout this document to describe the LPS operations concept.

1. Landsat 7 Contact Period: The time duration between the start and end of wideband data transmissions from the Landsat 7 spacecraft to a ground station. Figure 1-1 illustrates the Landsat 7 contact period concept.

2. Interval: The time duration between the start and stop of an imaging operation (observation) of the Landsat 7 ETM+ instrument.

3. Sub-Interval: A segment of raw wideband data interval received during a Landsat 7 contact period. Sub-intervals are caused by breaks in the wideband data stream due to communication dropouts and/or the inability of the spacecraft to transmit a complete observation (interval) within a single Landsat 7 contact period. The largest possible sub-interval can be as long as a full imaging interval. The smallest possible sub-interval can be as small as one full ETM+ scene with a time duration of approximately 24 seconds. Figures 1-1 and 1-2 illustrate the sub-interval concept.

4. Level 0R Files: The reformatted, unrectified sub-interval data having a sequence of pixels which are spatially consistent with the ground coverage and appended with radiometric calibration, attitude, and ephemeris data. Figure 1-2 illustrates the relationship of LPS files to the received sub-intervals.

Level 0R Instrument Data File: Each file contains the image data from a single band in a single subinterval. The data is grouped by detectors, i.e., for a given major frame, detector 1 data is followed by detector 2 data etc. Reverse scans are reversed. This data is nominally aligned using fixed and predetermined integer values (provides alignment for band offset, even/odd detectors, and forward and reverse scans). Quality indicators are appended for each major frame.

Calibration File: One file is created for each sub-interval. This file contains all of the calibration data received on a major frame basis for a given sub-interval. This is the data received after the Scan Line Data (which follows the End of Line Code) and before the next major frame sync, as described in Applicable Document 3. The data is grouped by detectors, i.e., for a given major frame, detector 1 data is followed by detector 2 data etc. Reverse scans are reversed. The spacecraft time of

the major frame corresponding to this data is appended, as well as the status data.

Mirror Scan Correction: One file is created for each sub-interval. This file contains the Scan Line Data extracted from the two minor frames following the End of Line Code in each major frame of the sub-interval . The Scan Line Data includes the first half scan error (FHS ERR), the second half scan error (SHS ERR), and the Scan direction (SCN DIR) information. The spacecraft time of the major frame corresponding to this data is appended.

Payload Correction Data (PCD): One file created for each sub-interval. This file contains the PCD major frames received during a subinterval on a full PCD cycle basis. Quality indicators will be appended on a minor frame basis.

5. Browse Image File: A reduced data volume file of the Level 0R data which can be viewed to determine general ground area coverage and spatial relationships between ground area coverage and cloud coverage. Browse image data from 3 predefined bands of the ETM+ Format 1 scene data are contained in the multi-band browse file. This file contains reduced resolution scenes of the full resolution scene data contained in the Level 0R instrument data files. There is a separate browse image file for each scene in a sub-interval.

6. Metadata: One metadata file is created for each sub-interval. The metadata contains information on the Level 0R data provided in the sub-interval, and the names of the Level 0R instrument data, calibration data, PCD, MSCD and browse image files associated with the sub-interval. Metadata also contains quality and accounting information on the return link wideband data used in generating the Level 0R file(s). In addition, metadata includes quality and accounting information on received and processed PCD, and cloud cover assessment for the Worldwide Reference System (WRS) scene contained in the sub-interval. The metadata is used by LP DAAC users to determine the sub-interval and/or WRS scene level quality of the Level 0R data stored in the LP DAAC archive before ordering it on a cost basis.

7. Return Link Quality and Accounting Data: The data quality and accounting information collected by LPS from Consultative Committee for Space Data Systems (CCSDS) Grade 3 and Bose-Chaudhuri-Hocquenghem
(BCH) error detection and correction processing of the raw wideband data received from LGS on a Landsat 7 contact period basis.

8. Level 0R Quality and Accounting Data: The data quality and accounting information collected by the LPS, on a sub-interval basis, from processing of the ETM+ major frames constructed from the wideband Virtual Channel Data Units (VCDUs) received during a Landsat 7 contact period.

FIGURE 1-1: Landsat 7 Contact Periods Concept

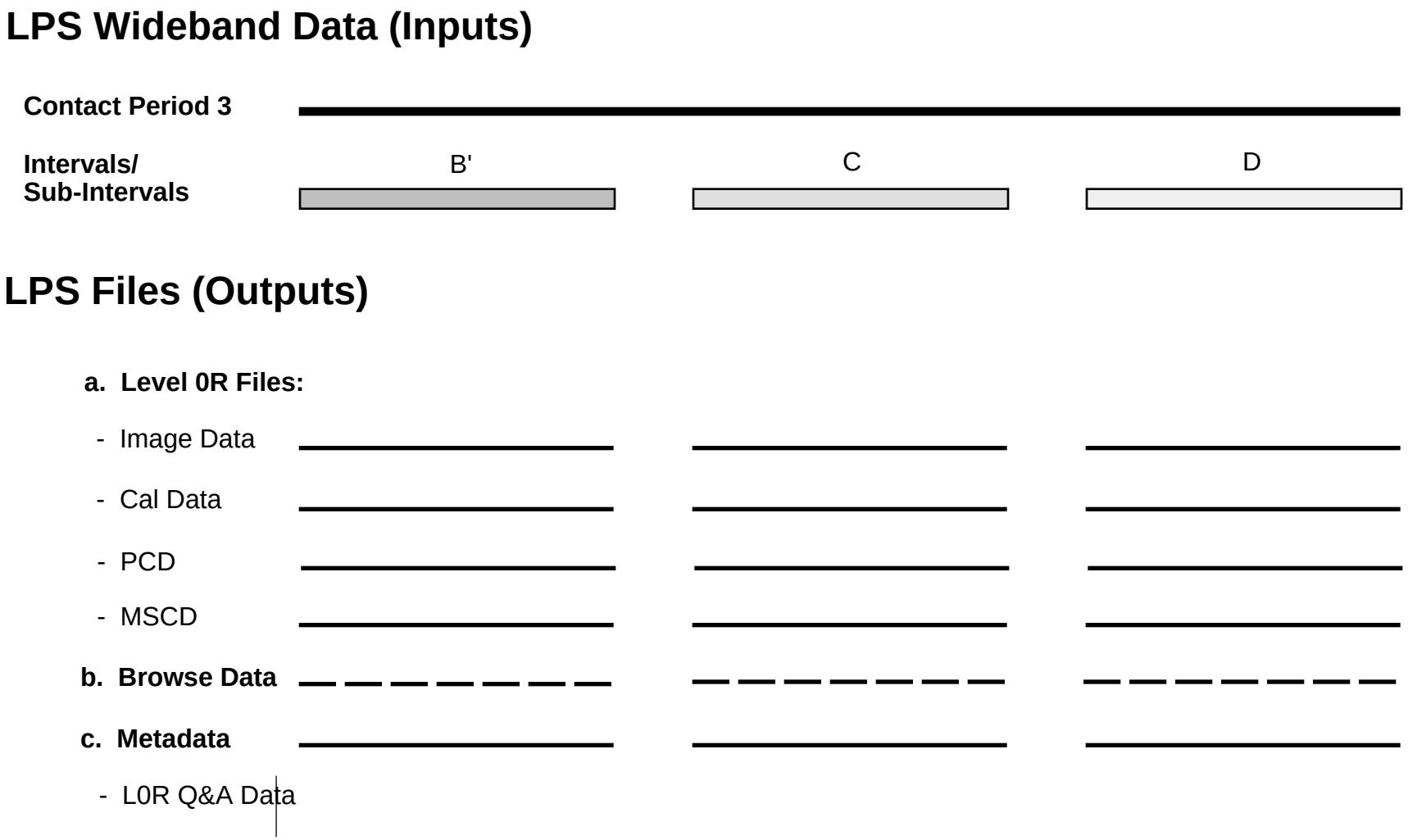

Figure 1-2: LPS Files for Landsat 7 Contact Period 3

9. LPS Files: The generic term used to denote the grouping of Level 0R, browse and metadata files for a single sub-interval. See Figure 1-2.

10. LPS String: A functional entity of the LPS responsible for end-to-end processing of the raw wideband data received from a return link channel (I or Q) of the X-band downlink data captured by the LGS.

1.4 LPS Environment

The LPS is a major component of the Landsat 7 System. Figure 1-3 provides a high level overview of the Landsat 7 System.

The Landsat system is a major satellite system, which uses a sun-synchronous, near polar orbit satellite and ground elements to provide wide-area multi-spectral imaging of the earth. The Landsat satellite provides remote sensing of the earth, returning data which can be processed by a ground processing system into images, or utilized in a digital form in a variety of scientific, military, and commercial applications. The Landsat system supports global change research, national security, and civil and commercial objectives. The system benefits domestic and international users in both the public and private sectors. The current Landsat 7 mission is a joint effort of NOAA, NASA, and the United States Geological Survey (USGS) to upgrade
the existing Landsat system to continue to provide improved and enhanced services to the Landsat users.

The Landsat 7 system consists of flight components (including the Landsat 7 satellite), and ground components (including the LPS). The Landsat 7 flight components are responsible for launching, placing, and maintaining the Landsat 7 satellite into a sun-synchronous orbit on the WRS for conducting remote sensing observations of the earth. The WRS consists of 233 fixed ground track paths and 248 rows. The WRS system is used by the Landsat system to uniquely identify a total possible of 57,784 WRS-centered scenes. As shown in Figure 1-4, the Landsat 7 system's flight plan is designed to repeat the coverage of these WRS scenes on a 16-day cycle. The ground components are responsible for planning, scheduling, monitoring and controlling the satellite remote sensing operations, as well as receiving, processing, archiving and distributing the earth observation data to the Landsat users.

The Landsat 7 satellite is equipped with the ETM+ instrument (also called the payload) which is capable of collecting terrestrial data in 8 specific spectral ranges, each associated with a specific spectral band. Bands 1, 2, 3, 4, and 8 of the ETM+ instrument collect the terrestrial data in the visible and near infrared (VNIR) spectral range, which is between 0.4 and 1.0 micrometers.

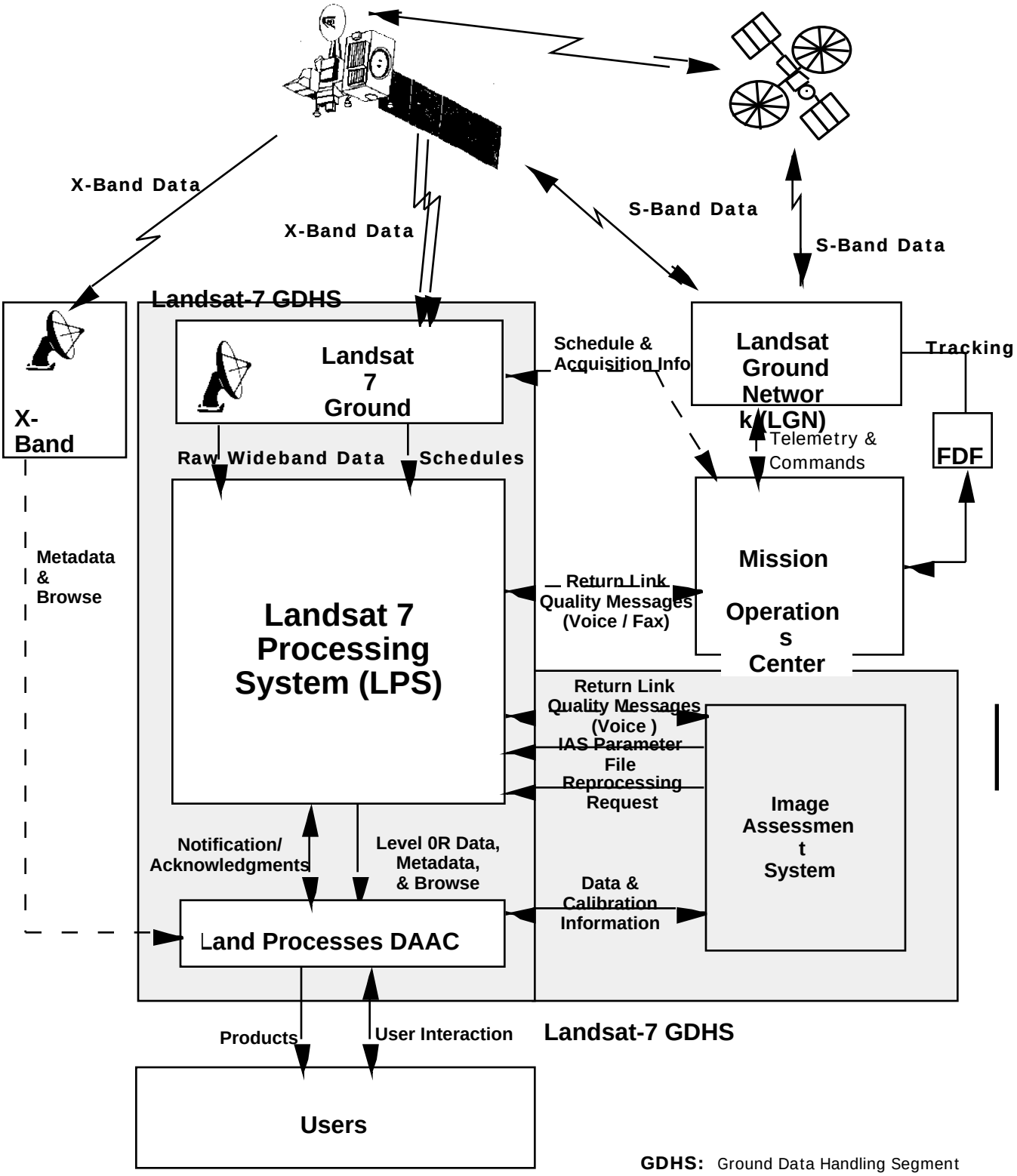

Figure 1-3: Landsat 7 Ground Data System

Figure 1-4 is available electronically in Interleaf only. A hard copy can be obtained from LPS Project or systems engineering personnel.

Bands 5 and 7 are the short wavelength infrared (SWIR) bands with a spectral range between 1.0 and 3.0 micrometers. Band 6 is the thermal long wavelength infrared (LWIR) band with a spectral range between 8.0 and 12.0 micrometers. Band 8, called the PAN band, is also used for panoramic image mapping.

The ETM+ is a fixed position nadir viewing "whisk-broom" instrument. The viewing swath is produced by means of an oscillating mirror that sweeps across-track as the sensor field of view (FOV) moves forward along track due to satellite motion. Calibration data is inserted in conjunction with each scan-mirror cycle. The layout of ETM+ bands and detectors on the instrument focal plane is provided in Applicable Document 3. Image data can be collected in low-gain or high-gain modes (i.e., lower or higher eight of the nine available output bits per pixel) for each spectral band. Image data will routinely be collected in the low-gain mode for the PAN, VNIR, and SWIR bands, and in high gain for the LWIR band (Band 6). Specific bands may also be switched to high or low gain modes, as necessary in some seasons, or upon user request. The ETM+ provides output data via two 75 Mbps channels. Channel 1 contains multiplexed data from Bands 1, 2, 3, 4, 5 and 6. Channel 2 contains multiplexed data from Bands 6, 7 and 8. Band 6 data is duplicated in both channels. Both channels also contain time, status and payload correction data associated with the image data in the channels.

The Landsat 7 satellite uses an on-board wideband solid state recorder to capture real-time imaging data from the two 75 Mbps band multiplexer channels when the data cannot be transmitted to the ground in real-time. The recorder can hold 378 gigabits of imaging data (84 minutes at the 75 Mbps rate). When a ground station is in sight, the Landsat spacecraft uses two of its three 150 Mbps X-band direct downlinks to simultaneously transmit both the real-time and recorded image wideband data to the ground station (e.g., the LGS).

The LPS is located, along with the LGS and the LP DAAC, at the EDC. The LGS is responsible for acquiring the ETM+ wideband data directly from the Landsat 7 spacecraft via two 150 Mbps X-band return links, separating each X-band data into two 75 Mbps I and Q channels, and transmitting the acquired wideband data over four 75 Mbps LGS output channels to the LPS.
The LGS receives Landsat 7 contact period schedules from the MOC. The LPS coordinates its operations with the LGS in accordance with the Landsat 7 contact period schedules to receive raw wideband data, in real-time, from all four output channels of the LGS. The LPS stores all wideband data, at real-time rates, into its wideband data stores. Subsequently, the LPS retrieves and processes the raw wideband data, at lower than real-time rates, into Level

0R, browse image, and metadata files, and makes them available for transfer to the LP DAAC. LPS receives the equivalent of 250 ETM+ scenes per day of wideband data from a maximum of 6 LGS contacts per day with the Landsat 7 spacecraft. The duration of each Landsat 7 spacecraft contact period is not expected to exceed 14 minutes. The LPS is designated to operate 24 hours a day, seven days a week, on a continuous basis. It is expected to support Landsat 7 system operations for a minimum mission life of 5 years. Operational support capabilities provided by the LPS include end-to-end and verification testing of LPS functions and interfaces, hardware and software maintenance, and operator training. The LPS is required to support the Landsat 7 system integration and test activities before launch.

The LP DAAC is an augmentation of the Earth Observing System (EOS) Data and Information System (EOSDIS) with responsibilities for archiving and distributing the Level 0R instrument data, browse image, and metadata products to the Landsat users. Landsat users access the LP DAAC via commercial and special data communication networks to query the Level 0R archive, to order Level 0R products, to check status of their orders, and to receive Level 0R products and invoices for the orders filled by the LP DAAC. Other systems supporting the LPS operations include the IAS and the MOC.

1.5 LPS Goals and Objectives

LPS goals are the following:

a. Minimize LPS development and operations costs to support implementation of the Landsat 7 system within allocated budgets.

b. Consider portability and re-use of LPS software to assure successful insertion of higher performance technologies throughout LPS development and operations.

To accomplish these goals, LPS must satisfy the following objectives:

c. Exploit EDC's experience with previous Landsat missions and distribution of Landsat products to the Landsat users' community to develop and to enhance the processing of the Landsat 7 ETM+ wideband data to Level 0R. Exploit GSFC's experience in developing systems compliant with recommendations of the CCSDS to reduce LPS implementation costs and risks.

d. Consider extensive use of commercial-off-the-shelf (COTS) products, hardware and software to implement the LPS. Emphasize life-cycle cost (LCC) considerations in making design decisions and meeting LCC, reliability, maintainability, and availability (RMA) requirements, as well as minimizing LPS staffing.

e. Seek active participation and technical reviews from EDC throughout the LPS development. Implement operational and/or functional enhancements to LPS in response to EDC suggestions that are consistent with LPS requirements and meet the LPS budgetary constraints. Identify operational and/or functional alternatives in response to EDC suggestions that are not within scope of LPS requirements and exceed the LPS budgetary constraints.

f. Plan LPS system and software development with emphasis on the reuse of LPS software to support insertion of higher performance hardware products (e.g.: processor upgrade or replacement), when available, to continually improve LPS system throughput and response times.

1.6 Assumptions

The following assumptions have been made in developing the LPS operations concept:

a. The Landsat 7 orbit schedule does not deliver more than 3 back-to-back passes (Landsat 7 contact periods) to the LGS and LPS at EDC.

[Consideration: The LPS operational concept allows for the receipt and retention of raw wideband data from up to 3 back-to-back Landsat 7 contact periods. This consideration involves controlling the competition for resources by the LPS functions and minimizing their impacts on the LPS wideband data receive and store operations. As a result, the LPS may not be able to complete processing of any one of the three Landsat 7 contact periods before they are all fully received by the LPS. This arrangement is not expected to affect the LPS turn-around times for making the Level 0R files available to the LP DAAC.]

b. The LGS will coordinate Landsat 7 contact period schedules with the LPS.

[Consideration: The LPS operations concept depends on this assumption to receive all scheduled wideband data from the LGS. LPS will coordinate with LGS to receive the wideband data on the I and Q channels for each X-band received by the LGS.]

c. The LP DAAC coordinates with the LPS and accepts a complete set of LPS output files on a contact basis.

[Consideration: The LPS performs Level 0R processing of the raw wideband data on a contact period basis. However, the LPS operations concept relies on sub-interval based data management

within each LPS string. Data Availability Notices (DANs) to the LP DAAC will be provided on a contact basis.]

d. LP DAAC is responsible for ensuring the receipt of all LPS files of a sub-interval from the LPS strings before initiating subsequent processing.

[Consideration: The LP DAAC operations concept requires the availability of all LPS files from the sub-intervals of a Landsat 7 contact period (all Level 0R, browse image, and metadata files from both the I and Q channels of an X-band return link) before it can start subsequent processing. The LPS will make files available to the LP DAAC on a contact basis, thus providing all files from both channels for all sub-intervals. LP DAAC is responsible for verifying the successful transfer of all files from both channels (represented by two LPS strings).]

e. The LPS will receive the ETM+ sensor alignment information and other parameters from the IAS only a few times during the Landsat 7 mission operations.

[Consideration: The LPS receives this data in electronic form from the IAS. This data is ingested automatically by the LPS upon operator command to update the LPS set-up tables.]

1.7 Applicable Documents

These documents were used in describing the LPS operations concept.

1. Consultative Committee for Space Data Systems (CCSDS), Recommendation for Space Data System Standards; Advanced Orbiting Systems (AOS), Networks and Data Links: Architectural Specification, Blue Book, CCSDS 701.0-B-1, Issue 1, October 1989

2. National Aeronautics and Space Administration (NASA) Goddard Space Flight Center (GSFC) Landsat 7 System Specification, Review issue, 430-L-000-2-A, August 1994

3. Martin Marietta Astro Space (MMAS), Landsat 7 System Data Format Control Book (DFCB), Volume 4 - Wideband Data, Revision B 23007702-IVB, May 15, 1995

4. NASA GSFC, Interface Control Document (ICD) between the Landsat 7 Ground Station (LGS) and the Landsat 7 Processing System (LPS), Signature Copy, May 26, 1995

5. NASA GSFC, Interface Control Document between the EOSDIS Core System (ECS) and the Landsat 7 System, Final, 209-CD-013-001, July 1995

6. NASA GSFC, Memorandum of Understanding (MOU) between the Landsat 7 Processing System and the Mission Operations Center (MOC), May 1995

7. NASA GSFC, Interface Control Document between the Landsat 7 Processing System and the Image Analysis System (IAS), Document No. 513-3FCD/0195**,** August 1995

8. NASA GSFC, Landsat 7 Detailed Mission Requirements, January 1995

1.8 Reference Documents

These documents contain background and/or detailed information on the various topics and terms used in the LPS operations concept description.

1. GSFC/MO&DSD, Systems Management Policy, MDOD-8YMP/0485, July 1986.

2. NASA GSFC/MO&DSD, Landsat 7 Processing System (LPS) Functional and Performance Specification, Revision 1, 560-8FPS/0194, July 28, 1995.

3. National Aeronautics and Space Administration (NASA) Landsat 7 Level 1 Requirements, Draft Issue, August 8, 1994.

4. United States Geological Survey (USGS)/National Oceanic and Atmospheric Administration (NOAA), Index to Landsat Worldwide Reference System (WRS) Landsats 1, 2, 3, and 4, 1982.

5. MO&DSD, Mission Operations Concept for the Landsat 7 Ground System, Document # **TBD**, Draft, June 1995.

6. Consultative Committee for Space Data Systems (CCSDS), Recommendation for Space Data System Standards, Telemetry Channel Coding, Blue Book, CCSDS 101.0-B-3, May 1992.

Section 2 — LPS Overview

This section provides an overview of key LPS operations concepts.

2.1 LPS Description

The LPS is a major component of the Landsat 7 system. LPS is located, along with the LGS and the LP DAAC, at the EDC. LGS is responsible for acquiring the ETM+ wideband data directly from the Landsat 7 spacecraft via two 150 Mbps X-band return links, separating each X-band data into two 75 Mbps I and Q channels, and transmitting the acquired wideband data over four 75 Mbps LGS output channels to the LPS. The LGS provides a fifth 75 Mbps spare output channel to be used as a backup for its four primary channels. The LPS coordinates its operations with the LGS in accordance with the Landsat 7 contact period schedules to receive the return link wideband data, in real-time, from all four output channels of the LGS into its four wideband data stores, one per LPS string. Each LPS string retrieves the received wideband data from its wideband data store and processes it at a rate equal to or greater than 7.5 Mbps, generates Level 0R, browse, and metadata files (collectively called the LPS files), and makes the LPS files available for transfer to the LP DAAC. The LPS also provides a fifth spare string to be used as backup for its four primary strings.

The LPS receives return link wideband data from the LGS on a Landsat 7 contact period basis and generates Level 0R, browse image, and metadata files on a sub-interval basis. The LPS moves to 30-day storage and processes the daily volume of wideband data from the LGS into Level 0R, browse, and metadata files within 16 hours of its receipt at the LPS. The LPS receives the equivalent of 250 ETM+ scenes of wideband data from the LGS, processes the data to LPS files, and provides the files to the LP DAAC on a daily basis. The LPS can reprocess (receive from LGS or LPS storage, process to Level 0R, browse image, and metadata files and provide the LPS files to the LP DAAC) the equivalent of 25 ETM+ scenes of wideband data on a daily basis (10 percent of the LPS required daily volume). The LPS maintains the overall processing throughput performance as long as the raw wideband data received from the LGS meets the bit error rate (BER) of 1 bit error in 10^5 bits.

The LPS also generates return link data quality and accounting information from the wideband data received on a Landsat 7 contact period basis. The LPS provides Level 0R quality and accounting information as part of the metadata to the LP DAAC for each of the sub-intervals processed from each

Landsat 7 contact period. The LPS also provides a moving window display capability for monitoring the quality of the received ETM+ data while it is being Level 0R processed at each LPS string.

The LPS consists of a total of five logically independent processing strings.
Four strings are used to support normal operations while the fifth string is the back-up, test, development, and training string. Figure 2-1 illustrates the LPS interconnect architecture.

2.2 LPS External Interfaces

The following subsections describe each of the external interfaces of the LPS.

2.2.1 Interface to LGS

Each LPS string interfaces with an LGS output channel. Each LPS string is responsible for receiving the Landsat 7 return link wideband data from its interfacing LGS output channel. A full complement of the LPS-to-LGS interface consists of four sets of LGS channels and four LPS strings. Each set of LGS channels is capable of transferring the acquired wideband data at the real-time rate of 75 Mbps. The LPS also coordinates its operations with the
LGS to configure its fifth (spare) string with any of the five LGS output channels for backup of either an LGS output channel or an LPS string.

The LPS receives the ETM+ return wideband data via the four 75 Mbps LGS
output channels into its four wideband data stores, one each for its four
logically independent strings. The LPS uses the Landsat 7 contact period schedule, available to the LGS from the MOC and made available to the LPS by the LGS in electronic form, to coordinate its operations with the LGS. The LPS receives all wideband data from the LGS on a Landsat 7 contact period
basis. Once all wideband data from a scheduled Landsat 7 contact period has
been successfully received by the four LPS strings, the LPS informs the LGS
of the successful receipt of all wideband data in its wideband data stores.

In the event of an LGS failure during LPS data receipt, the LPS will save, process and forward all data received during the contact period until the LGS

failure. The LPS will process partial contact periods and partial sub-intervals. Identification and processing of partial scenes may not be possible under these circumstances, but partially received data (including data from a single I or Q channel) will be processed by the LPS. Partial contact periods and partial sub-intervals will be made available for transfer to the LP DAAC.

The LPS also moves the raw wideband data, received from the LGS, to removable media on a LPS string basis for each Landsat 7 contact period. The LPS labels each removable medium before saving it in the LPS 30-day storage. The removable medium label contains, at a minimum, information on the received Landsat 7 contact period start and stop times, the source of the data (X Band receiver number plus the I or Q channel) used for receiving the wideband data, and the LPS string that captured the data. After completion

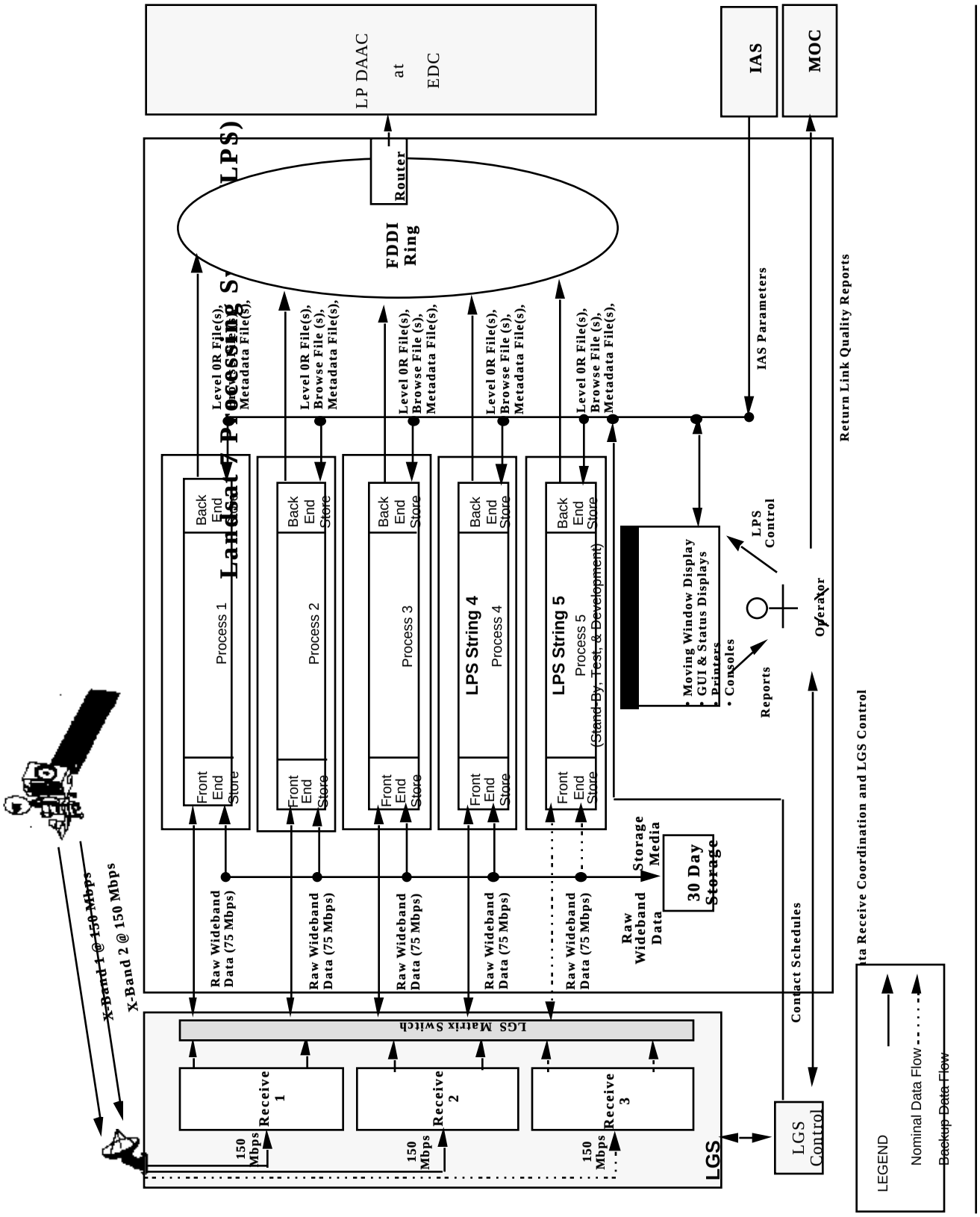

Figure 2-1: LPS Interconnect Architecture

of Level 0R processing, the LPS saves all removable media associated with the processed wideband data in the LPS 30-day storage. When required, upon receipt of a reprocessing request, the LPS retrieves the removable media, recorded with requested ETM+ wideband data, from the LPS 30-day storage. The LPS returns the removable media back to the 30-day storage after reprocessing of the requested wideband data.

2.2.2 Interface to LP DAAC

The LPS has a direct interface with the LP DAAC to exchange data transfer coordination messages and to transfer LPS files on a contact basis. Once all wideband data from a Landsat 7 contact period is processed by the LPS, the LPS provides an electronic notification, containing the LPS file list for a processed contact period, to the LP DAAC, to indicate the availability of LPS files in its output store. The LP DAAC transfers the Level 0R, browse image, and metadata files (LPS files) from the LPS output store. No LPS backup capability, such as a tape copy, is provided for LPS to LP DAAC electronic transfer. The LP DAAC provides a Data Delivery Notice (DDN) to the LPS to indicate receipt of successfully transferred files for a notified contact period. The LP DAAC is responsible for ensuring that it has received all LPS files from the two LPS strings associated with the I and Q channel of a Landsat 7 X-band before starting subsequent processing. The two LPS strings, associated with the I and Q channels of an X-band, are recognized by their LPS files with matching and/or overlapping start and stop spacecraft times.

2.2.3 Interface to MOC

The LPS forwards, via voice or FAX interface, the wideband data receipt summary to the MOC within 5 minutes of data receipt at the LPS, to consult/confirm the receipt of poor quality return link wideband data during Landsat 7 contact periods.

2.2.4 Interface to IAS

The LPS receives sensor alignment information and other parameters in electronic form from the IAS. The LPS will receive the sensor alignment information a few times during Landsat 7 mission operations. The first set of information is expected to be available to the LPS soon after the Landsat 7 launch. The LPS uses this information to manually update the LPS setup tables required during integer-pixel alignment processing of the ETM+ sensor data (during generation of Level 0R files).

The LPS receives return link wideband data reprocessing requests from the

IAS.

2.3 LPS Functions

The following functions are performed by each LPS string.

2.3.1 Receive Wideband Data

The LPS receives the ETM+ return link wideband data from the LGS on an
LGS output channel to an LPS string basis. The LPS coordinates its operations with the LGS in accordance with the Landsat 7 contact periods to receive the ETM+ wideband data, in real-time and on a Landsat 7 contact period basis, from the LGS. The LPS stores all wideband data, as it is being received from the LGS, in the LPS raw wideband data store. The LPS operations design is to start wideband data processing after completion of wideband data receipt. At present, the Landsat 7 data acquisition and transmission timelines indicate that, depending on the wideband data storage solution chosen for the LPS, the LPS may have to retain wideband data for up to three (3) back-to-back Landsat 7 contact periods before all data for a full Landsat 7 contact period can be successfully retrieved for processing to Level 0R by the LPS. The LPS also records all received wideband data on a Landsat 7 contact period basis on removable media for saving in its 30-day storage.

The LPS also provides a predefined test data set to test and verify the LPS
functions on an LPS string basis.

2.3.2 Generate Level 0R File(s)

The LPS retrieves wideband data from the wideband data store and performs
CCSDS Advanced Orbiting Systems Grade-3 service on the received Channel Access Data Units (CADUs). The CCSDS Grade 3 service processing includes frame synchronization and Pseudo-Random Noise (PN) decoding of the received CADUs, performing Cyclic Redundancy Check (CRC) on VCDUs and Reed-Solomon (R-S) error detection and correction of VCDU headers. Next, the mission data and data pointer contained in each VCDU are processed through BCH error detection and correction processing, and mission data errors are corrected, if required. The CADUs are then checked for Virtual Channel ID (VCID) consistency. Return link quality and accounting

information from these activities is collected throughout the Landsat 7 contact period. CADUs failing CRC checks and correction through R-S and BCH error
detection and correction processing are stored in a trouble file.

The LPS uses VCDUs, pre-checked for VCID-consistency, to extract PCD bytes from the status information contained in the VCDU, to synchronize on PCD minor frames, and to construct PCD major frame words. The LPS also identifies ETM+ minor frames present in the mission data zone of the VCDUs. The presence of each new major frame is verified by the LPS by monitoring the receipt of properly formatted and positioned minor frames containing ETM+ major frame synchronization, time code and end of line information as specified in Applicable Document 1. As each major frame is being constructed, the LPS uses the ETM+ scene data Format 1 or Format 2 selection information, contained in the status information in the VCDU, to perform deinterleaving of spectral bands contained in the minor frames and to reverse every other scan line, also in accordance with the information contained in Applicable Document 1. In addition, integer-pixel alignment of the ETM+ bands and detectors for both the forward and reverse scans is performed, and the ETM+ sub-intervals are determined within the received Landsat 7 contact period. The LPS also extracts calibration and MSCD from each ETM+ major frame to generate calibration and MSCD files on a sub-interval basis. Both files are tagged with spacecraft time. The PCD file is also generated on a sub-interval basis. Status information extracted from the first VCDU of each major frame is appended to each major frame.

The Level 0R files are built on a VCID basis to ensure that switching of the I and Q channels of a Landsat 7 X-band return link does not mix the ETM+ data from two different VCIDs with the same spacecraft time in the same Level 0R file. In other words, the LPS processes all wideband data from a Landsat 7 contact period on a VCID basis within each physical channel. Under normal circumstances, the LPS processes the same contact period on both the I and Q channels of the X-band data received from the LGS.

2.3.3 Generate Browse File(s)

A browse image is a lower resolution image for determining the geographical coverage, information content, and image quality of the Level 0R data. Multiband browse image files are generated for each scene using 3 predefined bands from the Level 0R instrument data, and applying the Wavelet algorithm for performing image reduction. Band identifiers will be parameterized at the beginning of processing for each contact. The multiband browse is generated only for the Level 0R instrument file containing the ETM+ Format 1 scene data. The LPS uses a reduction factor of 16 or better to generate the browse images. The LPS also provides the capability to annotate

each browse image with a limited set of alphanumeric and/or binary data for identifying the browsed WRS scene images.

2.3.4 Generate Metadata File(s)

The LPS generates a metadata file for each sub-interval. The metadata provides information on the identification and quality of the Level 0R instrument data contained in a sub-interval. Metadata also includes return link data quality and ETM+ instrument data quality statistics, quality and accounting information on the received and processed PCD, and cloud cover assessment on both WRS scene and quadrant bases.

The LPS identifies and locates the WRS scenes contained in each sub-interval. The LPS uses the WRS scene information to determine the cloud coverage on both WRS scene and quadrant bases and to identify WRS scene boundaries in the browse image data (file). The LPS uses parameterized pixel comparison values to perform automatic cloud cover assessment (ACCA) of ETM+ scene data. The ACCA information is included in the metadata.

2.3.5 Transfer LPS File(s)

Once the LPS files (Level 0R, browse image, and metadata files) have been generated and are available in the LPS output store, the LPS notifies the LP DAAC of their availability, on a contact basis, for each LPS string. Upon receipt of this notification, the LP DAAC transfers the available files from the LPS output storage to its data archive storage. After successful transfer by the LP DAAC, the LPS receives an acknowledgment from the LP DAAC on the receipt of the LPS files. Unless the operator has marked the files for retention, the LPS deletes all files that the LP DAAC acknowledges as successfully transferred when the acknowledgment is received.

In the event of unsuccessful transfers, the LPS retains all LPS files not yet transferred to the LP DAAC until the LP DAAC can successfully retrieve them after correction of the transfer problem. The LPS retains the files until the LP DAAC has successfully retrieved them and has provided an acknowledgment to the LPS. If, for any reason, the LP DAAC is unable to retrieve the LPS files from the LPS output storage within 8 hours of data availability and the LPS output storage is full, the LPS will stop processing the received wideband data from its raw data store. The LPS, however, continues to receive raw wideband data in accordance with the Landsat 7 contact period schedules, and record them to removable media for subsequent retrieval and processing by the LPS.

2.3.6 Control LPS Operations

The LPS provides monitoring and control capabilities for successfully managing the LPS operations on a LPS string basis during all automated operations. The LPS provides log-on protection for each LPS string. The LPS may allow the operator to monitor processing operations of any set of the five LPS strings from a single operator interface (terminal). The single operator interface to LPS strings provides only limited communication between strings, for example to propagate level 0R processing parameters.

The LPS collects quality and accounting information when it processes data on a Landsat 7 contact period basis. The LPS also generates summary reports on the amount of Landsat 7 data received, processed and delivered to LP DAAC on a Landsat 7 contact period, and on a daily basis. These summary reports can be displayed and/or printed upon LPS operator request.

[Paragraph Deleted]

The LPS uses manual controls to accomplish the following LPS activities:

a. Update the source of data being captured by each LPS string.

[Paragraph Deleted]

[Paragraph Deleted]

[Paragraph Deleted]

b. Start and stop wideband data retrieval from removable media.

c. Configure LPS strings to LP DAAC communication interfaces to make LPS files available to the LP DAAC.

d. Allocate and configure the fifth string to support LPS operations, or LPS test, maintenance, training, and development activities.

e. Override LPS automated operations to capture data, perform level 0R processing, save raw wideband data to removable media, or retain or delete successfully transferred LPS files, as required.

f. Monitor LPS automated processing operations.

[Paragraph Deleted]

g. Display and/or print LPS summary reports including quality and accounting summaries.

h. Monitor the moving window display of the ETM+ instrument data

being Level 0R processed at each LPS string.

2.4 LPS Conceptual Architecture

The LPS consists of a total of five logically independent strings. Each string independently interfaces to one of the LGS output channels to receive the Landsat 7 ETM+ wideband data. During a contact period, four of the five strings receive wideband data from the LGS. The fifth LPS string is used as backup when one of the four strings assigned to LPS operations goes down due to a malfunction. The backup string is configured, available, and ready for switch over during all data capture operations. When not required and not used to support LPS operations, the fifth string is available to support LPS maintenance, functional and interface testing, training, and development activities.

Each LPS string consists of three key components -- wideband data store, LPS process, and output store. The wideband data store component is capable of receiving the return link wideband data at the real-time rate of 75 Mbps and providing it at a rate equal to or greater than 7.5 Mbps to the LPS process component. The LPS process processes the retrieved wideband data into LPS files, including Level 0R, browse image, and metadata files, and stores them in the LPS output store. The output store retains the LPS files until they are successfully transferred to the LP DAAC. If the LPS output storage is full while the LP DAAC is unable to retrieve files, the LPS will retain the untransferred files in the output store and will continue to receive data from the LGS. LPS processing will be disabled until the LP DAAC has transferred the retained files and space has been freed in LPS output storage. Each LPS string is capable of processing ETM+ Format 1 or Format 2 scene data.

The LPS conceptual architecture, once implemented, is expected to provide an Operational Availability (Ao) of 0.96 or better. During a 10,000 hour period (417 days), 104,250 scenes (250 scenes per day) can be collected, and an Ao of 0.96 is met with no more than 400 hours of system down-time. Assuming the worst case when a failure occurs, all three contacts are lost on one string and loss of data is equal to 13.5 GB (24 minutes at 75 Mbps), or 60 scenes which contain one format. The LPS backup string will be brought on line to capture the next 3 contacts, so failure time is assumed to be 12 hours. The worst case number of failures (equal to down time/time per failure, or 400/12) is 33 in a 10,000 hour period, and requires a Mean Time Between Failures (MTBF) of 303 hours (10,000/33). If, during one failure, 60 scenes are partially lost, 33 failures result in a total of 1,980 scenes partially lost during a 10,000 hour

period. The Ao for the worst case scenario is, therefore, 0.981 [(104250 - 1980)/104250].

The LPS implementation uses COTS items, where possible in its design, to support Landsat 7 mission operations for a minimum of 5 years. The LPS components will be carefully selected and/or designed to assure an LPS BER of 1 bit error in 10^9 bits.

2.5 LPS System Support

The LPS configuration includes a full set of software tools, utilities, and "canned" test data sets to support LPS hardware and software maintenance, verification testing of LPS functions and interfaces, enhancement and development of LPS capabilities, and training, as required.

LPS system support includes training of EDC personnel in the operations and maintenance of the LPS. During system transition, this support is based on the use of the training courses and training materials available from the LPS COTS item vendors and from GSFC and GSFC contractors, such as the SEAS contractor, supporting the LPS development. During mission operations, the EDC is responsible for using the delivered training materials and system documentation for developing and providing the required training to its personnel.

Section 3 — LPS Operations

The following section describes LPS operations scenarios, for normal and contingency operations.

3.1 Nominal Operations

This scenario describes the major operational activities performed by the LPS.
This description is concerned with activities for nominal operations only. The sequence and details of the steps that describe the activities are typical. LPS design considerations may alter these steps.

3.1.1 Normal Operations

Normal LPS operations consist of performing the following activities on a
daily basis:

a. Receive Landsat 7 contact period daily schedules at least six (6) hours in advance from the LGS.

b. Review Landsat 7 contact period schedules to prepare for LPS daily operations.

Normal LPS operations consists of performing the following activities on a
Landsat 7 contact period basis:

c. Verify configuration and/or configure LPS strings to receive wideband data from the LGS in accordance with the received Landsat 7 contact period schedules.

d. Verify operational readiness of the LPS hardware and software resources at least 15 minutes before the start of each Landsat 7 contact period. Ensure that the LPS wideband data store and output store have adequate storage space available before starting wideband data receive/retrieve and Level 0R processing operations.

e. Coordinate the start of wideband data receipt with the LGS.

f. Verify that the automatic scheduled data capture process is ready to capture approximately 15 seconds before the start time of the Landsat 7 contact period (allows for acquisition of signal (AOS) by the LGS).

g. At the Landsat 7 contact period start time, verify the start of the receipt of return link wideband data from the LGS with the LGS operator.

h. Continually monitor wideband data receipt and record operations through the end of the Landsat 7 contact period.

i. Verify the start of wideband data retrieval for LPS processing, if required.

j. Verify the start of the recording of the received wideband data onto removable media.

k. Verify loss of signal (LOS) with the LGS. Verify that the automatic scheduled data capture process has stopped. Also verify the recording of all wideband data received for the whole Landsat 7 contact period.

l. Ensure that the LPS wideband data store is available to support retrieval of wideband data for Level 0R processing, if required.

m. Review Landsat 7 contact period schedules to prepare for the receipt of the wideband data from the LGS for the next Landsat 7 contact period, if required.

n. Continually monitor wideband data retrieval and processing operation.

o. Continually monitor recording of wideband data onto removable media.

p. Verify, from LPS-displayed messages, the completion of LPS processing, the generation of LPS files, and their availability in the LPS output store.

[Paragraph Deleted]

q. Verify transmission of the LPS data availability notification to the LP DAAC.

r. Verify the start of LPS file retrieval by the LP DAAC.

s. Verify the receipt of an acknowledgment from the LP DAAC on the successful transfer of LPS files.

t. Verify, from LPS messages, that successfully transferred LPS files are deleted from the LPS output storage.

u. Display and/or print LPS summary report(s) for the processed Landsat 7 contact period:

- LPS quality and accounting report

[Paragraph Deleted]

- LP DAAC Files transfer summary report

v. Label removable media containing the wideband data for the Landsat 7 contact period just processed by the LPS.

w. Save removable media in the LPS 30 day storage.

3.1.2 Sensor Alignment Table Update Operations

This operation involves performing the following steps:

1. Receive voice or hard-copy notification from the IAS that a new IAS parameters file is available.

2. Follow LPS operational procedures to determine the best time to update the LPS databases. At that time, log on using a privileged account. Updates can be made only from a privileged account and not from operator accounts. Only authorized personnel will have the password to access the privileged account.

3. Transfer the IAS parameters file from the IAS to the file system on the test and development string.

4. Invoke LPS software to ingest the IAS parameters into a LPS database on the test and development string.

5. Verify the ingested parameters against the IAS parameter file's contents, for example by printing and comparing the two.

6. Perform level 0R processing on a test data set to verify the update and the operability of the new parameter values. This step can be performed from an operator account on the test and development system. Coordinate with the IAS to resolve problems. Problem resolution may involve repeating (a subset of) steps 2 through 5.

7. When operability of parameter values has been verified, invoke LPS software to propagate the parameter files from the test and development system to the databases on the four production strings. This step must be performed from the privileged account.

8. Verify that the propagation was successful by monitoring the output of the propagation process.

9. Proceed with normal operations.

10. Verify with IAS and/or LP DAAC that the LPS files received by them show a successful update of LPS setup tables with the latest sensor alignment information received from the IAS.

11. Resolve problems, if verification is negative. Problem resolution may involve repeating (a subset of) steps 2 through 10.

3.1.3 Wideband Data Reprocessing Operations

The LPS may need to reprocess wideband data available in its storage areas. The LPS is capable of reprocessing ten percent of the daily workload from
either its raw wideband data store or from the LPS 30-day storage. In most instances, reprocessing will only be necessary during LPS and/or LP DAAC
contingency situations, and most reprocessing requests are expected to be for data in 30-day storage. This LPS operation identifies the following steps required to reprocess the wideband data from the LPS 30-day storage:

a. Receive a request to reprocess wideband data from the IAS.

b. Identify the wideband data requiring reprocessing in LPS storage.

c. If the requested data is still available in LPS storage, configure LPS processing string(s) to start reprocessing. (This may involve searching for and retrieving the requested wideband from the LPS raw wideband data store or from the LPS 30-day storage.)

d. Start retrieval of the requested wideband data.

e. Continually monitor the wideband data retrieval and processing operation.

f. Verify, from LPS displayed messages, the completion of LPS processing, the generation of LPS files and their availability in the LPS output store.

g. Verify transmission of the LPS data availability notification to the LP DAAC.

h. Verify the start of the retrieval of LPS files by the LP DAAC.

i. Verify the receipt of an acknowledgment from LP DAAC on the successful transfer of LPS files. (Allow some time for the LP DAAC to transfer the reprocessed wideband data/LPS files.)

j. Verify, from LPS messages, that the successfully transferred LPS files are deleted from the LPS output store.

k. Display and/or print LPS summary report(s) for the reprocessed wideband data:

- LPS quality and accounting report
- LP DAAC file transfer summary report

l. Close wideband data reprocessing operation.

3.2 Contingency Operations

The following scenarios describe recovery operations due to anomalies, either internal or external to the LPS. These scenarios will be augmented, as required, as new LPS contingency scenarios are identified during LPS design.

3.2.1 LGS Failure

An LGS failure may be detected by the LPS operator observing the LPS wideband data receipt operation or may be reported to the LPS by the LGS
operator. The LPS operation consists of performing the following steps to identify and to recover from an LGS failure.

a. Verify LGS failure with the LGS operator.

b. Follow established operational procedures and coordinate with the LGS operator to isolate the failure to either the LGS communication link or the LGS equipment.

c. Follow established operational procedures and coordinate with the LGS operator to switch-over to the LGS backup communication link/equipment, as appropriate.

d. Follow established operational procedures and coordinate with the LGS operator to recover from the LGS failure.

e. Verify with the LGS that the failure has been corrected.

f. Verify that the LPS successfully receives raw wideband from the LGS (either from the contact period already in progress or from the next contact period when it starts).

g. Report successful receipt (partial or full) of contact period to the LGS.

h. Follow operational procedures to report loss of wideband data to the MOC and the LP DAAC.

3.2.2 LPS Failure

LPS failures may be caused by the failure of any one of its four processing strings supporting the wideband data receipt, wideband data record, wideband data processing to Level 0R (LPS files generation), and LPS file transfer operations.

The LPS operation consists of performing the following steps to identify and recover from an LPS failure:

a. Identify a failure from error messages generated during LPS normal operations.

b. Inform the LGS operator if the failure is associated with the raw wideband data receipt operation.

c. Inform the LP DAAC operator if the failure is associated with the transfer of LPS files to the LP DAAC.

d. Follow operational procedures to attempt to isolate the LPS failure.

e. Initiate a request to configure the fifth string to support LPS operations, if necessary. Follow operational procedures to switch-over to the LPS backup string, when available.

f. Follow operational procedures to recover from LPS failure. Coordinate with the LGS and LP DAAC operators to reconfigure LPS strings and to return to normal operations.

g. Obtain assessment from maintenance personnel on the time required to repair the failed LPS string.

h. Follow operational procedures to determine if recovery of the received (in raw wideband store or on removable media of a good string) or processed (in LPS output store of a good string) data is required.

i. Start wideband data recovery operations during wait periods between the Landsat 7 contact periods.

j. Verify recovery of all recoverable data from the good LPS string. Continue with normal operations.

The LPS operation consists of performing the following steps to recover received/processed data from a failed LPS string:

k. Verify operability of the failed LPS string when returned from maintenance.

l. Start recovery of the wideband data stored on the failed LPS string. This may initially require processing of the wideband data to Level 0R while the failed string is still off-line.

m. Verify that the recovered LPS files are available to the LP DAAC. Inform the LP DAAC of the availability of recovered files.

n. Coordinate with the LP DAAC operator to temporarily switch over to the repaired string for making recovered LPS files available to the LP DAAC.

o. Verify that the LP DAAC receives notification of the availability of recovered LPS files.

p. Verify that the LPS receives acknowledgment from the LP DAAC on the successful receipt of recovered LPS files.

q. Follow normal procedures to report loss of data to the LP DAAC and the MOC.

r. Continue with normal operations.

3.2.3 LP DAAC Failure

LP DAAC failure may be caused by either the failure of the communication link between the LPS and the LP DAAC or by the failure of an LP DAAC
component designated to receive files from the LPS. An LP DAAC failure may be reported to the LPS by the LP DAAC operator, or the LPS operator may learn of an LP DAAC or communication link failure from an automated message received during LPS operations. The automated message may be generated by the communication software of the LPS or the LP DAAC. The LPS operation consists of performing the following steps to identify and to recover from an LP DAAC failure.

a. Disable deletion of available LPS files using the manual override capability.

b. Verify failure of either the LP DAAC or the communication link with the LP DAAC operator.

c. Follow operational procedures to isolate the LP DAAC failure to either the LP DAAC component or the communication link/equipment.

d. Follow operational procedures and coordinate with the LP DAAC to switch over to backup communication link/equipment, as appropriate.

e. Follow established operational procedures and coordinate with the LP DAAC to recover from the failure.

f. Verify with the LP DAAC that the failure has been corrected.

g. Receive acknowledgments from the LP DAAC of the successful receipt of available LPS files.

h. Process acknowledgments and continue with normal operations.

Acronym List

Ao	Operational Availability
ACCA	Automatic Cloud Cover Assessment
BCH	Bose-Chaudhuri-Hocquenghem (error detection and correction scheme)
BER	Bit Error Rate
CADU	Channel Access Data Unit
[DELETED]	
CCSDS	Consultative Committee for Space Data Systems
COTS	Commercial Off-the-Shelf
CRC	Cyclic Redundancy Check
[DELETED]	
DAN	Data Availability Notice
DCN	Document Change Notice
DOC	Department of Commerce
DOI	Department of the Interior
DDN	Data Delivery Notice
ECS	EOSDIS Core System
EDC	EROS Data Center
EOSDIS	Earth Observation Data Information System
EROS	Earth Resources Observation System
[DELETED]	
ETM+	Enhanced Thematic Mapper Plus (instrument)
FAX	Facsimile
FHS ERR	First Half Scan Error
FOV	Field of View
[DELETED]	
[DELETED]	
GDHS	Ground Data Handling Segment
GSFC	Goddard Space Flight Center
IAS	Image Assessment System
[DELETED]	
LCC	life-cycle cost
LFO	Landsat 7 Flight of Opportunity
LGS	Landsat 7 Ground Station
LPS	Landsat 7 Data Processing System
LP DAAC	Land Processes Distributed Active Archive Center
[DELETED]	

LWIR	Long Wavelength Infrared
Mbps	Megabits Per Second
MSCD	Mirror Scan Correction Data
[DELETED]	
MOC	Mission Operations Center
MO&DSD	Mission Operations and Data Systems Directorate
MTBF	Mean Time Between Failures
[DELETED]	
[DELETED]	
NASA	National Aeronautics and Space Administration
[DELETED]	
NOAA	National Oceanic and Atmospheric Administration
PCD	Payload Correction Data
PCMB	Project Configuration Management Board
PN	Pseudo-Random Noise
RMA	Reliability, Maintainability, and Availability
R-S	Reed-Solomon (error detection and correction scheme)
SCN DIR	Scan Direction
SEAS	Systems Engineering and Analysis Support
SHS ERR	Second Half Scan Error
[DELETED]	
[DELETED]	
[DELETED]	
SWIR	Short Wavelength Infrared
TBD	To Be Defined/Determined
TBR	To Be Resolved
[DELETED]	
USGS	United States Geological Survey
VCDU	Virtual Channel Data Unit
VCID	Virtual Channel Identifier
VNIR	Visible and Near Infrared
WRS	Worldwide Reference System